CMOS Sensors for the HFT :

Binary Output Chip Performances

M.W. (IPHC-Strasbourg)

OUTLINE

- **MIMOSA-16 beam tests results ⟶ m.i.p. detection performances vs discri. threshold**
  - ⁂ **detection efficiency**
  - ⁂ **fake hit rate**
  - ⁂ **single point resolution**
- **Extrapolation to next generations of chips**
  - ⁂ **consequence of different pixel pitch**
  - ⁂ **effect of noisy pixels**

⇒ **Where is the optimum ?**

- **Conclusion**

Introductory Remarks

- *MIMOSA-16 : $\sim$ fully tested chip with binary output*

  $\hookrightarrow$ prototypes architecture of PHASE-1

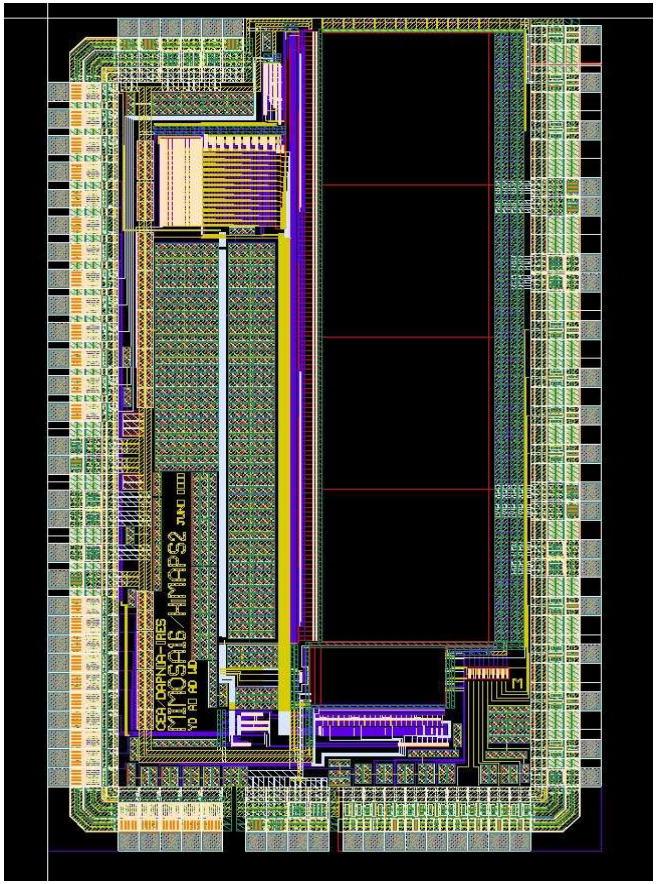
- **Evaluate whether architecture (AMS-0.35 OPTO) is mature for large scale chip :**
  - *range of discriminator threshold for which detection efficiency and fake rate are both OK ?*
  - *does this range allow for the ambitionned single point resolution ?*
  - *what about fakes ($\equiv$ noisy or hot pixels) ?*
  - *what about effects of radiation ? $\triangleright$ $\triangleright$ $\triangleright$not yet investigated*

- **Try to extrapolate observations to different pixel pitch**
  - *PHASE-1 : 30 μm*
  - *ULTIMATE : ????????*

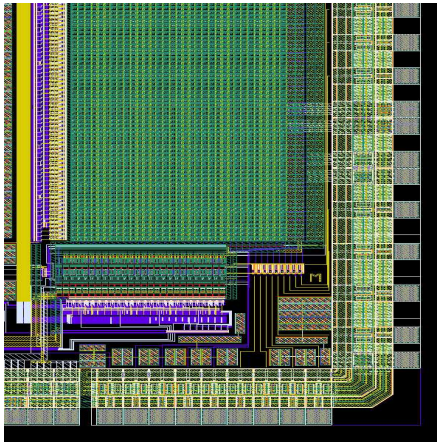
High R.-O. Speed Architecture : 2nd Prototype = MIMOSA-16

MIMOSA-16 design features :

- AMS-0.35 OPTO translation of MIMOSA-8
  $\hookrightarrow \sim$ 11–15 μm epitaxy instead of $\lesssim$ 7 μm
- 32 // columns of 128 pixels (pitch: 25 μm)
- on-pixel CDS (DS at end of each column)
- 24 columns ended with discriminator
- 4 sub-arrays :
  - S1 : like MIMOSA-8 (1.7x1.7 μm^2 diode)
  - S2 : like MIMOSA-8 (2.4x2.4 μm^2 diode)
  - S3 : S2 with ionising radiation tol. pixels
  - S4 : with enhanced in-pixel amplification
    (against noise of read-out chain)



$\Rightarrow$



Tests of analog part (”20” & ”14” μm epitaxy) :

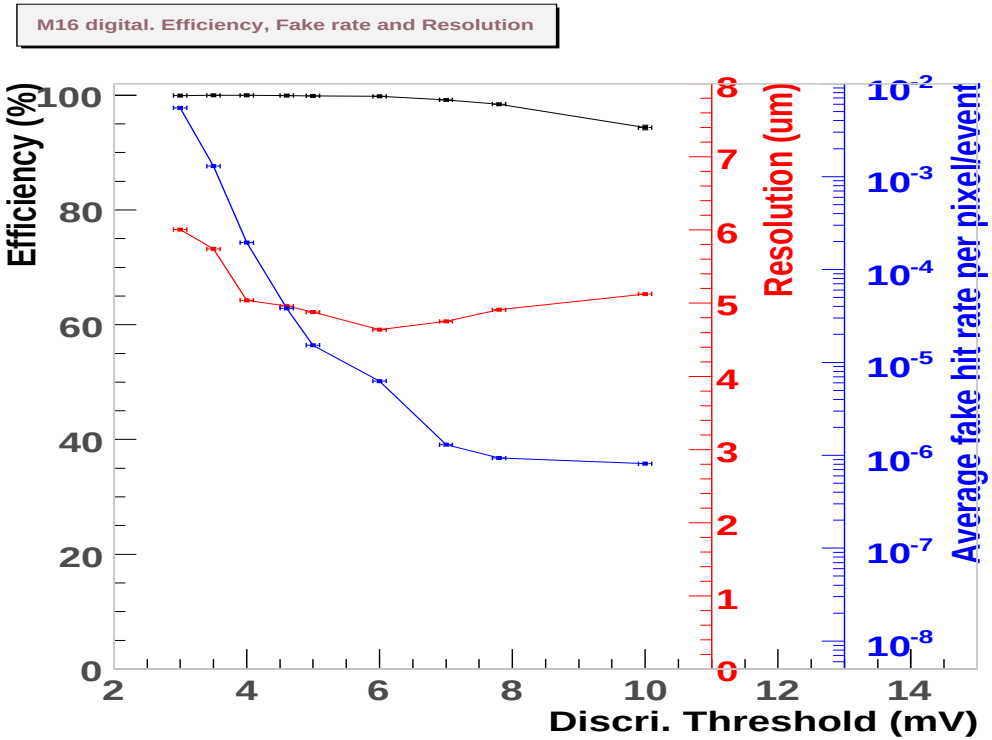
- sensors illuminated with ^{55}Fe source and $F_{r.o.}$ varied up to $\gtrsim$ 150 MHz
- measurements of N(pixel), FPN (end of column), pedestal variation, CCE (3x3 pixel clusters) vs $F_{r.o.}$

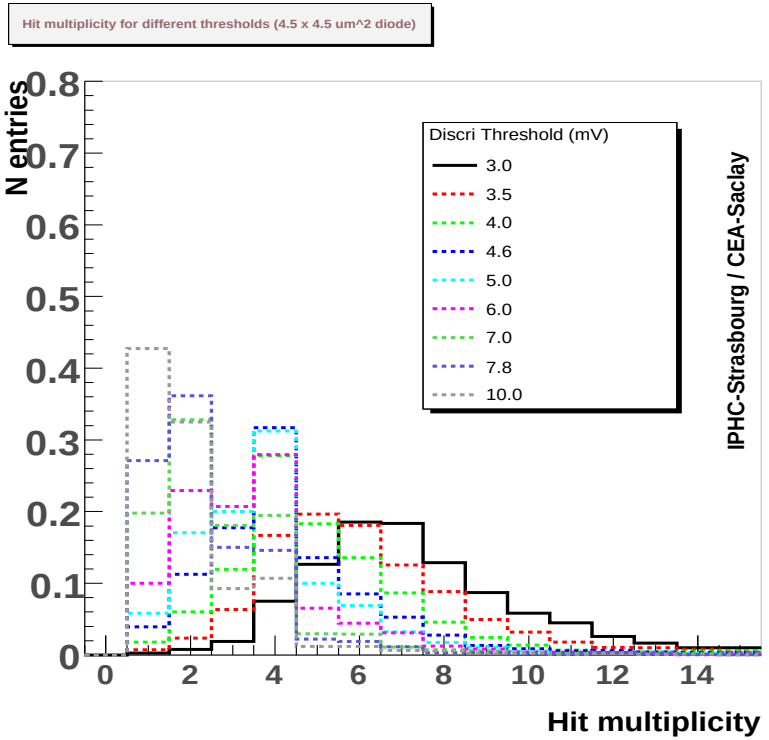
M.i.p. detection with Si-stip telescope studied at CERN in Sept. ’07 $\longrightarrow$ characterisation of digital response :

- π^- beam of $\sim$ 180 GeV/c
- measurements of SNR, det. efficiency, fake rate, cluster characteristics, spatial resolution vs discri. threshold

MIMOSA-16 Beam Test Results (Digital Part)

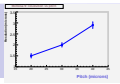
- **CERN-SPS ($\sim$ 180 GeV π^-) $\longmapsto$ results of S4 ("14 μm" epitaxy)**
- **Read-out time $\sim$ 50 μs** *($\sim$ 1/4 of max. freq. due to DAS limitations)*





- **Major result $\longmapsto$ at least one pixel architecture validated for next steps : S4 (SNR $\sim$ 16)**

Discri. Threshold	*det. efficiency*	*fake rate*	*sgle pt resolution*
4 m V	*99.96 $\pm$ 0.03 (stat) %*	*$\sim 2{\cdot}10^{-4}$*	*$\sim$ 4.8–5.0 μm*
6 m V	*99.88 $\pm$ 0.05 (stat) %*	*$<10^{-5}$*	*$\sim$ 4.6 μm*



- MIMOSA-16 Beam Test Results : Eff. vs Fakes

- **Investigate whether 1-pixel clutsers or 2-pixel clusters are more appropriate**

Nb(pix)/cluster	*1 pixel per cluster*		*2 pixels per cluster*	
Threshold (mV)	*Efficiency (%)*	*Fake rate*	*Efficiency (%)*	*Fake rate*
3.0 ± 0.10	*99.94 ± 0.04*	*5.51E-03±1.16E-05*	*99.66 ± 0.04*	*5.48E-04±3.66E-06*
3.5 ± 0.10	*99.96 ± 0.03*	*1.30E-03±6.11E-06*	*99.23 ± 0.03*	*3.11E-05±9.46E-07*
4.0 ± 0.10	*99.96 ± 0.03*	*1.94E-04±2.46E-06*	*98.16 ± 0.03*	*1.79E-06±2.36E-07*
4.6 ± 0.10	*99.94 ± 0.03*	*3.82E-05±1.06E-06*	*96.00 ± 0.03*	*7.76E-07±1.51E-07*
5.0 ± 0.10	*99.88 ± 0.05*	*1.53E-05±7.35E-07*	*94.07 ± 0.05*	*1.48E-06±2.28E-07*
6.0 ± 0.10	*99.79 ± 0.07*	*6.29E-06±3.82E-07*	*89.82 ± 0.07*	*6.91E-07±1.27E-07*
7.0 ± 0.10	*99.19 ± 0.13*	*1.30E-06±1.81E-07*	*79.56 ± 0.13*	*5.81E-07±1.21E-07*
7.8 ± 0.10	*98.43 ± 0.19*	*9.35E-07±1.57E-07*	*71.74 ± 0.19*	*5.84E-07±1.24E-07*
10.0 ± 0.10	*94.34 ± 0.41*	*8.12E-07±1.39E-07*	*54.03 ± 0.41*	*5.50E-07±1.14E-07*

- **1-pixel/cluster with high threshold is more effective ⟼ what about hot pixels after irradiation ?**

  ⇛ foresee 2-pixel requirement logic, to be activated if necessary after some data taking period

CONCLUSION

- **Architecture validated for PHASE-1 (in absence of intense radiation ....)**

  $\Rightarrow$ **binary output provides ambitionned single point resolution**

- **Still to do :**

  - *investigate effects of ionising and non-ionising radiation*
  - *(clarify effect of operating temperature ?)*

- **Extrapolation to PHASE-1 and ULTIMATE :**

  - *PHASE-1 : $\sim$ 30 μm pitch $\longrightarrow$ expected single point resolution $\sim$ 6 μm*
  - *ULTIMATE single point resolution from $\sim$ 4 μm ($\lesssim$ 20 μm pitch) $\longrightarrow$ $\sim$ 8–9 μm ($\sim$ 35 μm pitch)*

- **Questions :**

  - *Is a single point resolution of 8–9 μm in one dimension (rectangular pixels) acceptable ?*

    $\hookrightarrow$ *need also to study detection efficiency vs T, rad. dose, etc.*

  - **Several other aspects to investigate ????**